VIRTUAL PROTOTYPING APPROACH FOR THE DESIGN OF DIECAST FURNITURE COMPONENTS

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ABSTRACT

B&B ITALIA is a company with a mission focused on design innovation for furniture.
A lot of new products are developed every year, for private or collective destination, to satisfy the requirements of international market which is still more exigent.
To satisfy global market demands, in terms of safety and durability, european and international rules are the references.

Today more than yesterday, CAE models interfere in design phase and in each step of design chain production. Intelligent Digital Prototyping (iDP), common called virtual simulation, can efficiently embrace each step of design chain: mechanical behaviour, manufacturing, heat treatment and machining.
The described case history is a valid example of integration between structural analysis and process simulation to study a furniture diecasting component [4].
An accurate and reliable integrated methodology, based on virtual prototyping permits to control original investments , product costs, time to market and in particular can avoids start-up problems.

KEYWORDS
diecasting, aluminium alloy, numerical simulation, design chain

INTRODUCTION

Brilliant designers create B&B ITALIA products but it's not enough.
First impact on customer is the aesthetic point of view and it can establish the market appreciation.
A careful customer immediately realises the choice and quality of used materials, of manufacturing technology and finishing method adopted.
Only research and technology innovation allow to give life and shape at the designer idea warranting high level of quality.

Starting from the first idea of designers (free lance), synergical co-design of Center Research and Development (CR&D) can define the product concept.
The concurrent engineering activity starts when the style is defined and the project development takes into account established requirements in terms of shape, function and performance.
The engineering project starts often with measurement of mock up object available at CR&D, through a reverse engineering procedure.
3D parametric model is generated by optical scanning using laser source that can create a point set. CAD system define surfaces of model interpolating points and generating its trim curves.
Feasibility analysis means the definition of materials, manufacturing technology, investments and production costs. A preliminary structural analysis verifies dimensions and shape compared with first concept. In conclusion, the final model come of loop FEM calculations in order to satisfy the requirements of each department.

The design chain approach of ALMA chair (fig. 1a-b) shows a first configuration, in agreement with B&B ITALIA standards, that provided a frame with elastic plate for sitting.
This hypothesis, similar to beams-nodes structure, limits the stresses in the range of admissible material tensile values but it requires a seat thickness increasing from 20 mm to 35 mm. Without a positive opinion of designer, the engineering department proposes a second configuration with a aluminium diecasted plate solution accepting some comfort compromises (fig. 1c).

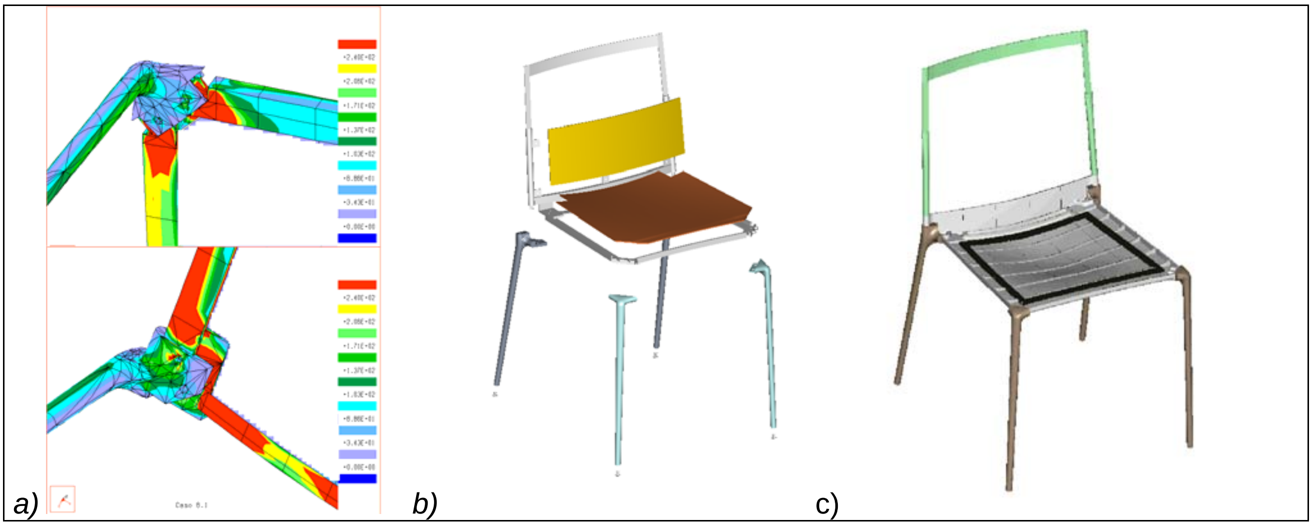


fig 1 – a) FEM analysis, b) first configuration of ALMA chair, b) plate solution

The final FEM analysis assure the dimensions and shape depending on testing loads that the product must support (fig. 1b).

fig 2 – a) ALMA chair, b) load testing

Parallel development activities save the time lost during the complex design phase. In fact, indispensable product presentation at Milan International exhibition, important annual appointment to show new furniture, requires steel die building to produce some prototypes using gravity casting process. Some prototypes are tested in laboratory to validate the project in agreement with optimised structural results (fig. 2).

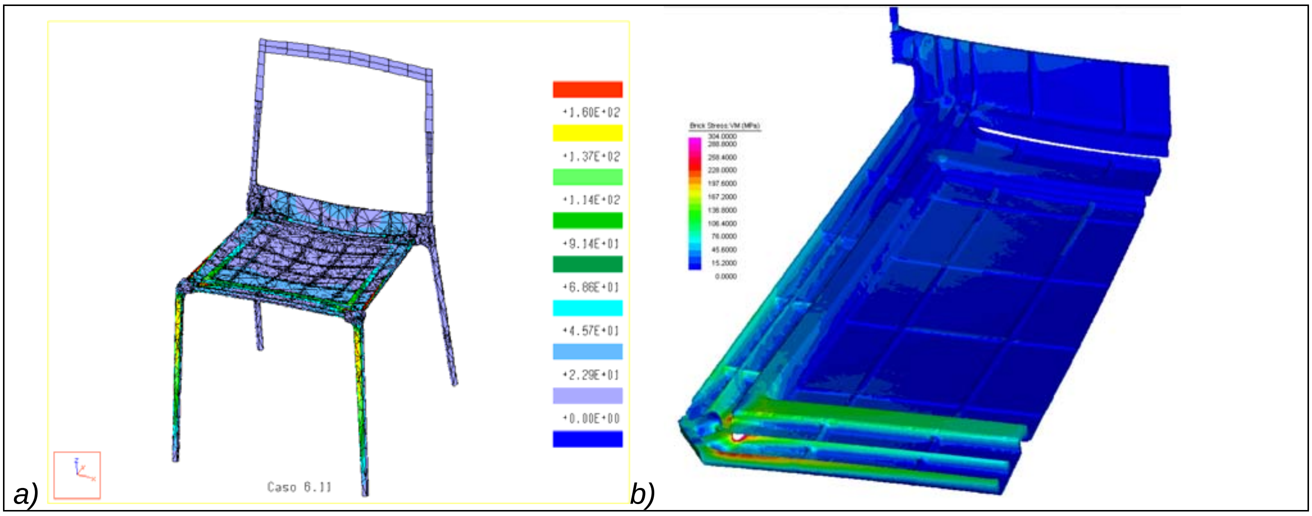
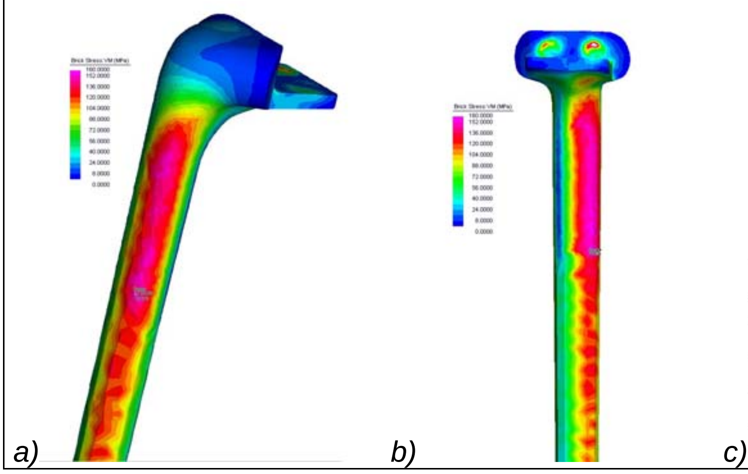


fig 3 – a) stresses on whole FEM model, b) Von Mises stresses on aluminium plate



a) b) c)

ALLOY	AlSi8Cu3.5 FeZnMg
Young Modulus	70000 MPa
Poisson	0.3
UTS	245 MPa as cast
Max Elongation	5 %
Hardness	95 HB

fig 4 – stresses of legs under service conditions a) front view, b) back view, c) alloy mechanical properties

Testing results confirm the mechanical behaviour predicted by FEM analysis. Picture 3 shows a pick of stress on the connection zone of leg and plate, while anterior legs (fig. 4) are subjected of admissible Von Mises stresses compared to aluminium alloy properties (fig. 4c).

With local changes the project is approved and during the gravity casting production, the die casting tools construction starts.
The chronological history described continue toward the testing phase for diecasted components finding out some evident limits: although structural analysis assured the 5^ level of UNI EN 178 quality, the anterior legs not satisfy the 4^ level during static load test.

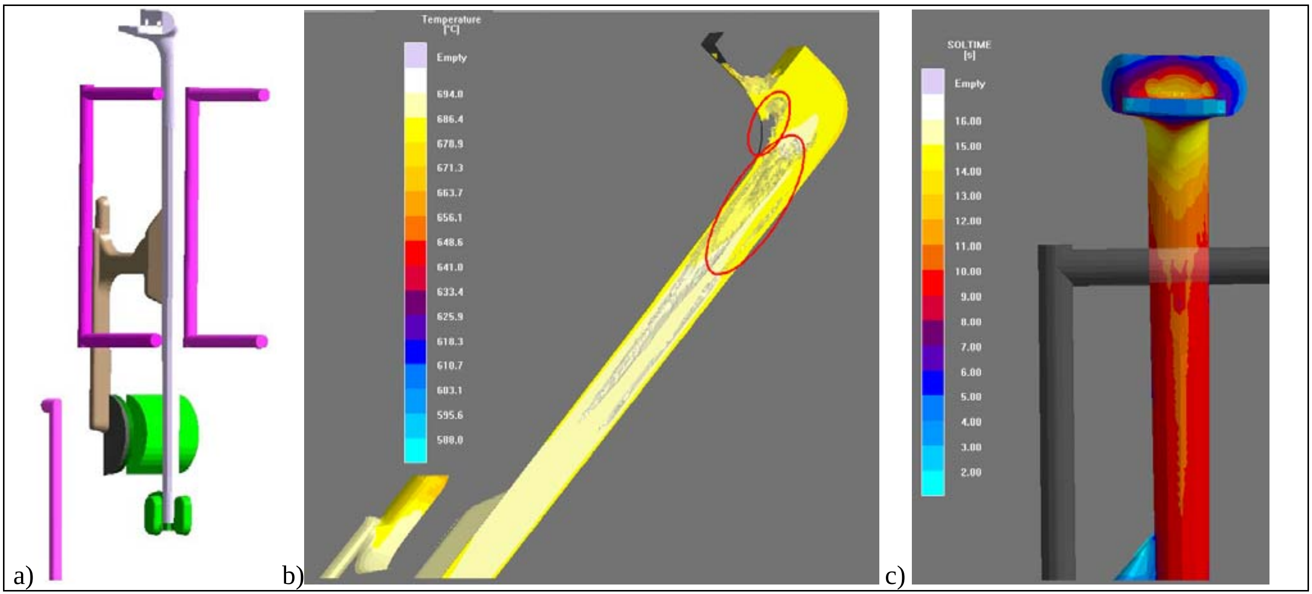
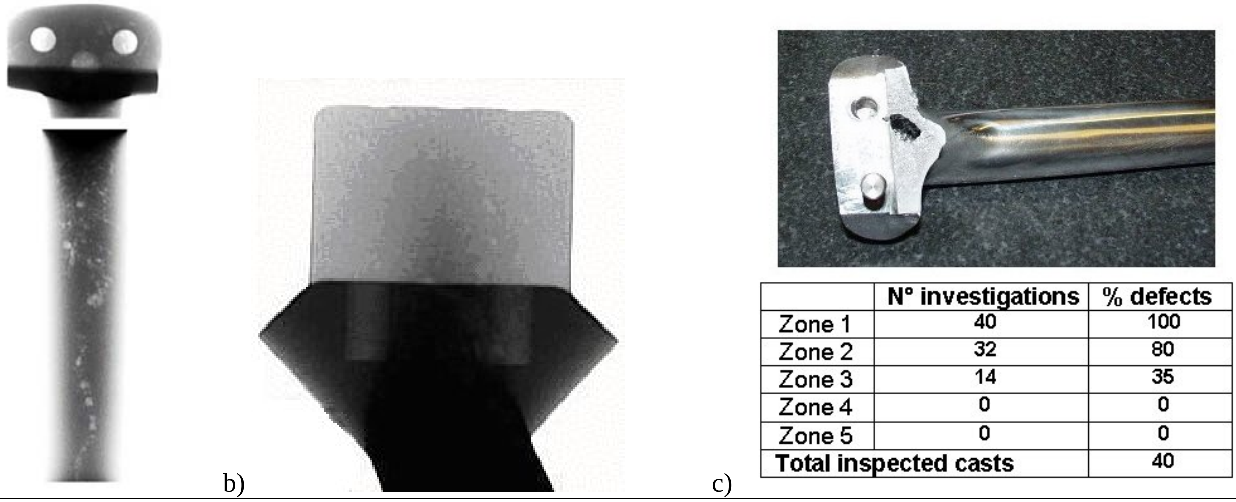


fig 5 – process simulation: a) numerical model, b) filling, c) solidification

Process simulation and microstructural investigations are focused on geometrical optimisation and diecasting process control to produce ALMA legs [5].
Even known that process simulation are efficient if adopted during design phase, as often happens, virtual prototyping is applied to understand the reason of verified production problems.
This approach is a testing to compare simulation results and reality with the aim to propose some tool improvements taking into account that the die is just built. It is possible to accept an advantage in terms of rapid die modifications suggested by simulation.
As mentioned, static and dynamic tests show critical strength problems near the leg-plate connection. The first FEM analysis cannot predicts the behaviour because the alloy mechanical

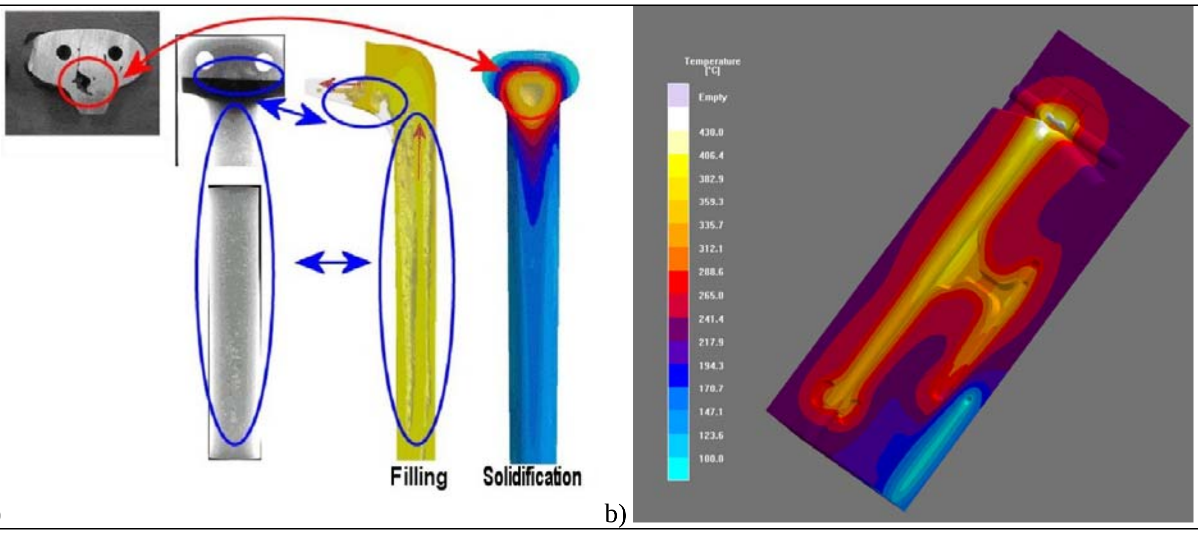
properties are considered uniform and isotropic (fig. 4c), as often happens, neglecting the real diecasting material characteristics.
Diecasting process simulation (fig. 5), considering two parts per die, and the experimental investigations (fig. 6) demonstrate, with no dubs, the presence of defects inside the critical zone.
Reasons of macro-porosity, that reduce mechanical properties, are gas entrapments and solidification shrinkage [1-5].



	N° investigations	% defects
Zone 1	40	100
Zone 2	32	80
Zone 3	14	35
Zone 4	0	0
Zone 5	0	0
Total inspected casts		40

a) b) c)

fig 6 – metallurgical investigations a) upper zone of leg, b) connection area, c) defect distribution



a) b)

fig 7 – Verified defects and simulation prediction: a) porosity, b) thermal load of die

Figure 7a describes reasons of defects clearly showed with X-ray method and sectioning: high melt velocity during the filling phase produce turbulence and vortex in particular in the massive upper zone of the stem; long solidification time in the same zone demonstrates high risk of shrinkage porosity. The distance between ingate and critical area is a considerable limit to feeds the contraction with application of over-pressure during the third process phase.
Moreover, as fig 7.b shows, the die temperature distribution at steady state points out a surface over-heating in the same critical zone.
A solution modifies the actual tools taking into account simulation and investigation results, foundry requirements, die builder ideas and customer standards (fig. 7).

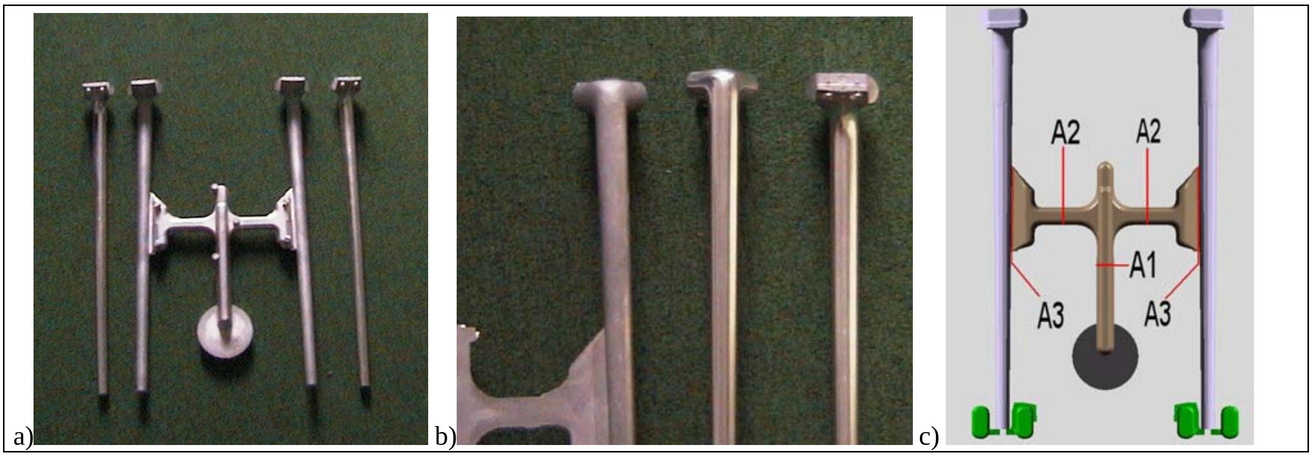


fig 8 – a e b) original production, c) die solution

Improved solution burns by new gating design, definition of injection curve and optimisation of die thermoregulation system.
Geometrical and process modifications, based on fluid-dynamic and solidification results, support foundry and die builder to produce diecasted legs that satisfy the 4^ quality level (fig. 8).

CONCLUSIONS

Experience above described suggests iDP approach, including FEM and process simulation analysis, for next diecasting furniture production. Virtual prototyping allows prediction of component behaviour taking into account mechanical properties estimated by process simulation and avoiding or reducing unwelcome manufacturing defects.

The case history provides useful suggestions of possible thrift introducing numerical simulation in the design phase.
Start-up costs and product investments could be reduced about 11-12 %, that represents the impact of metallographic investigations, tool modifications and furniture substitution after customer claim.
While time to market saving could be estimated about 20-22 % of total project cost, corresponding simply at experimental investigation time and die optimisation.

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